Electronic Linearization of Fiber Optic Links

Bahram Jalali
UCLA

Applications: **Radar, ECM**
HFC (CATV) broadcasting and VOD
Fiber-wireless networks

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Outline

- Introduction
- UCLA's previous work
- RFLIC project

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jalali@ucla.edu

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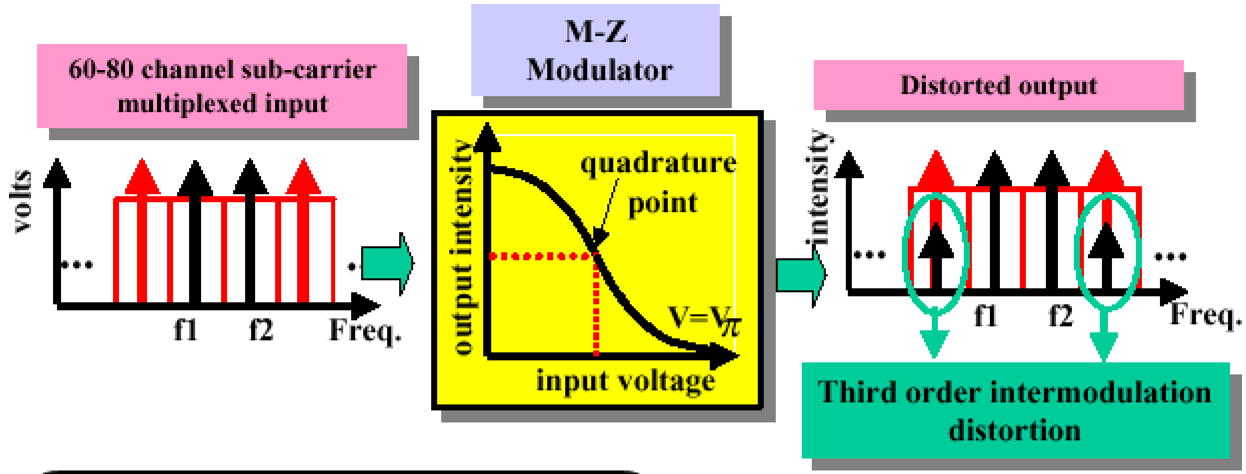
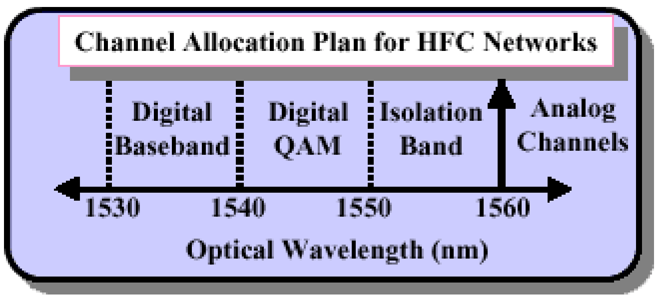
Example: Amplitude Modulated CATV Transmission





- Electro-Optic modulator has a sinusoidal transfer characteristic.
- Even order distortion minimized by operation at quadrature point.

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jalali@ucla.edu

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Problem with Today's Electronic Linearization Technology

•Operation is limited to ~750MHz

•Limited to MZ modulators

•Besides adjustment for bias point, there is no adaptive capability

•Solution are hybrid not monolithic

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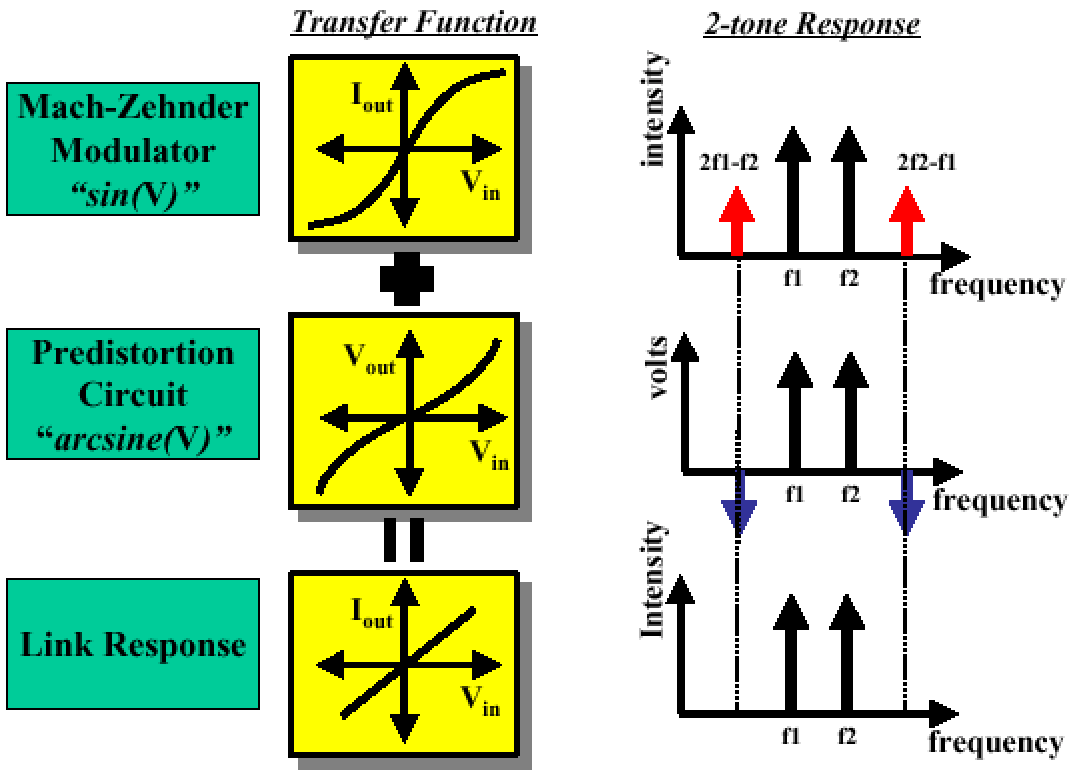
Predistortion Linearization



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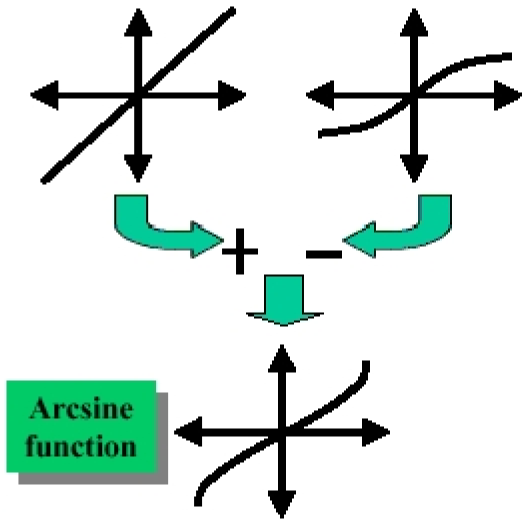
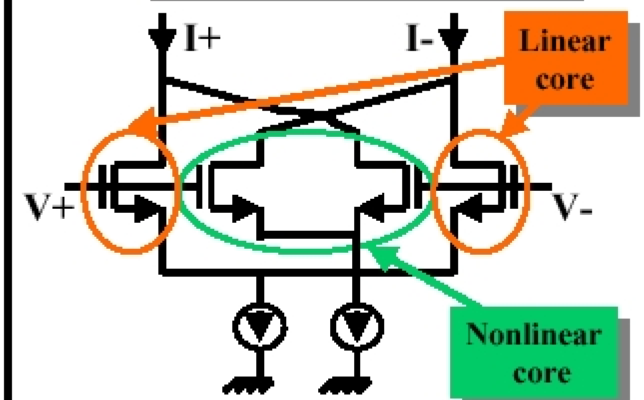
Predistortion Circuit Architecture

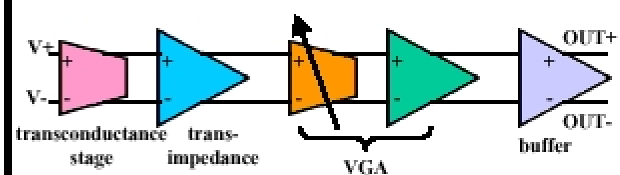
Synthesizing an arcsine function



With proper choice of transistor sizes, it can match an ideal *arcsine* up to 5th order

Circuit implementation with differential pairs





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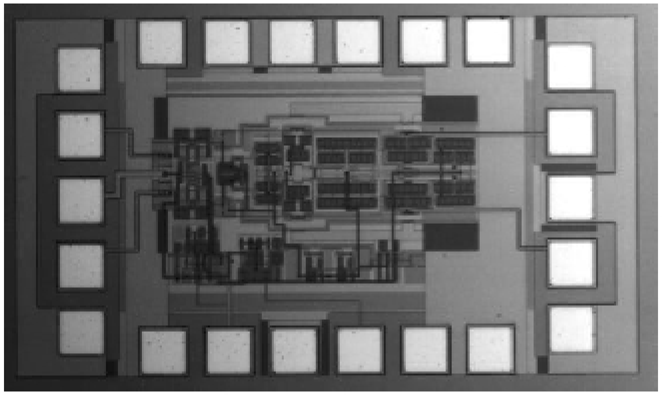
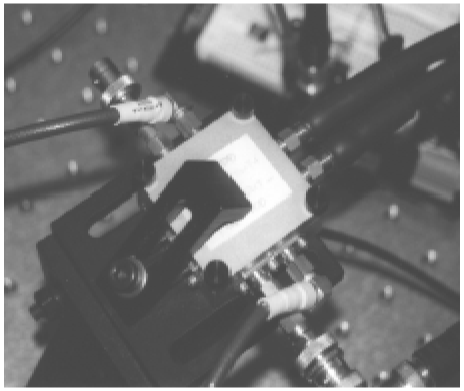
IC Fabrication and Packaging

Chip photograph. Area: 0.6x0.35 mm^2.
0.6 μm CMOS technology.



Test fixture
f_{max} = 10GHz



- First FET based linearizer
- First fully monolithic linearizer in any technology

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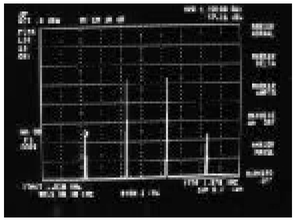
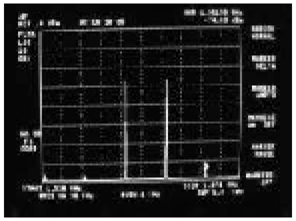
Broadband Electronic Linearization of Externally Modulated Links

1st Generation: 0.6 µm CMOS Measurement Results

- **17 dB IMP3 suppression from DC to 1.3 GHz at 49% modulation depth**
- **14dB improvement in SFDR**



Two tone test without linearizer circuit at 1.3 GHz

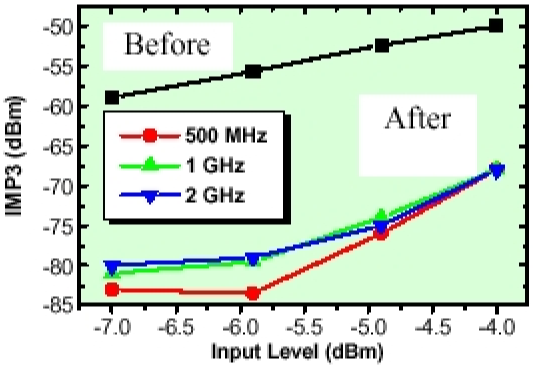


Two tone test with linearizer circuit at 1.3 GHz

Y. Chiu, B. Jalali et al., IEEE Photonics Technology Letters, January 1999.

2nd Generation: 0.35 µm CMOS

- **20 dB IMP3 suppression from DC to 1.7 GHz.**
- **On-chip variable gain amplifier.**



V. Magoon and B. Jalali, IEEE MWP 2000.

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jalali@ucla.edu

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Calculation of CTB Performance

N carriers, each at a modulation index β → $x - \alpha_3 x^3$ (Modulator) → Linear terms + Nonlinear distortion terms

$$\sum_{i=1}^{N} \beta \cos(\omega_i t + \theta_i) \; - \alpha_3 \beta^3 \left(\sum_{p=1}^{N} \sum_{q=1}^{N} \sum_{r=1}^{N} \cos(\omega_p t + \theta_p) \cos(\omega_q t + \theta_q) \cos(\omega_r t + \theta_r) \right)$$

$$P_3 = \left(4N_3(\omega_b) + N_2(\omega_b)\right) * P_{2T} = M * P_{2T}$$ → $$CTB = 10 * \log\left(\beta^2 / 2P_3\right)$$

P_3 = Distortion power falling into channel with carrier frequency ω_b

P_{2T} = Distortion power in a two tone test

$N_3(\omega_b)$ = Maximum number of incoherent combinations of three distinct frequencies falling on the channel centered at ω_b

$N_2(\omega_b)$ = Maximum number of incoherent combinations of two distinct frequencies falling on the channel centered at ω_b

$N_3(\omega_b)$ and $N_2(\omega_b)$ are determined by computer simulation*

* *Nazarathy et al, Journal of Lightwave Technology, January 1993.*

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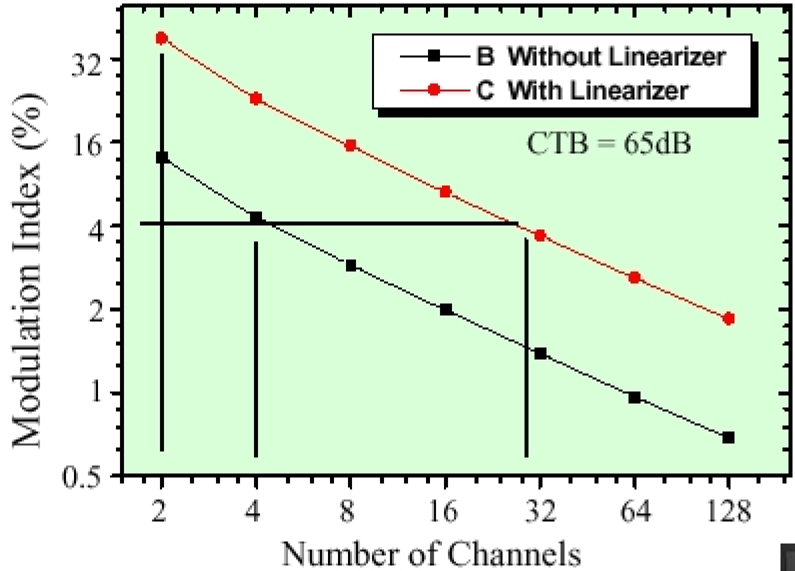
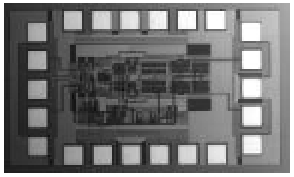
CTB Performance of the Linearizer





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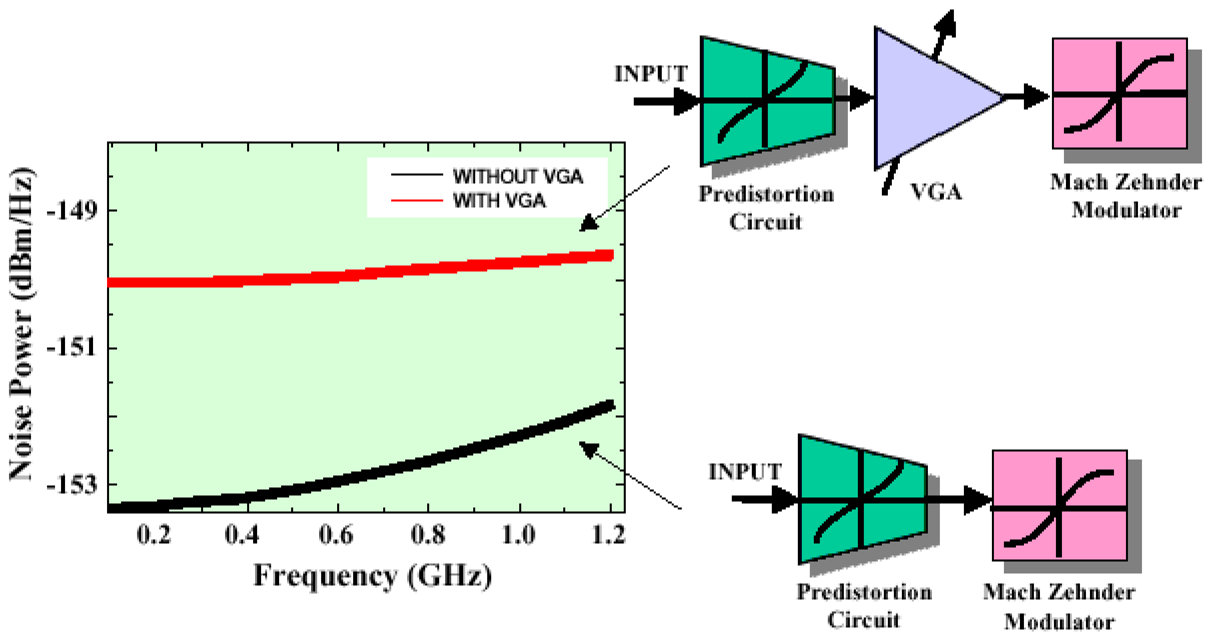
Noise Performance of Predistortion Circuit



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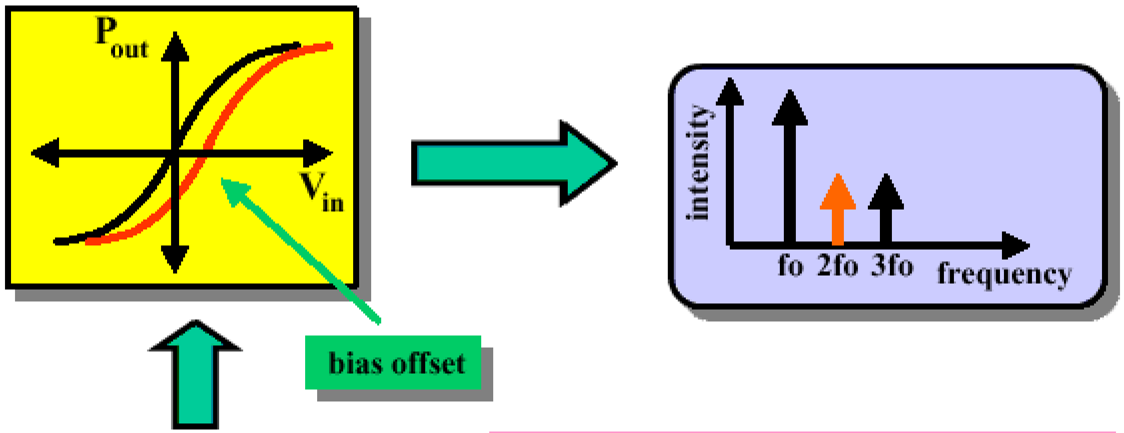
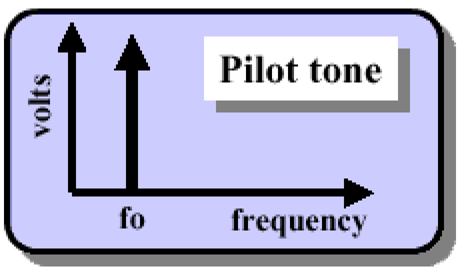
Bias Drift in Electro-Optic Modulator





- Bias point of the modulator drifts due to thermal and aging effects.
- Causes second order distortion
- Third order distortion largely independent of bias offset.

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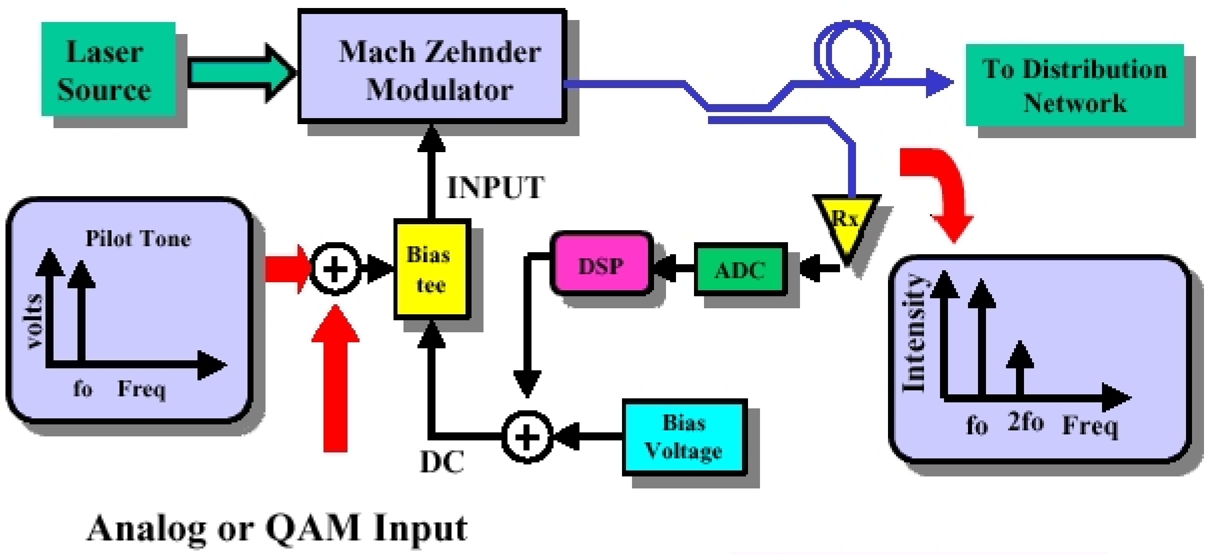
Integrated Bias Control Feedback Loop



- Digital solution
- Low power pilot tone

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jalali@ucla.edu

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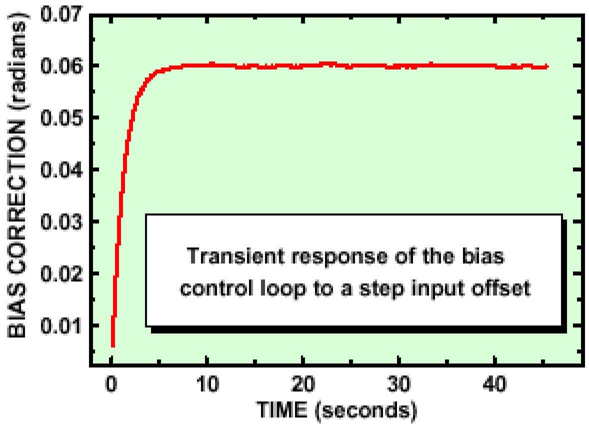
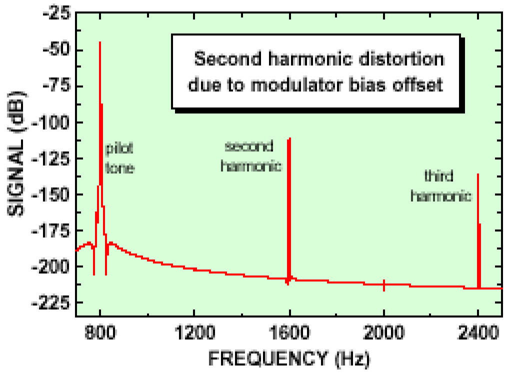
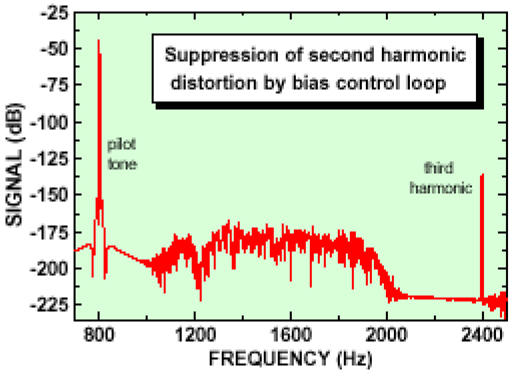
Simulated Performance of Bias Control Loop



- Bias drift variation occurs over long periods of time
- Loop locks to within 0.5mrad offset in 5 seconds
- Signal spectrum shows strong suppression of second harmonic





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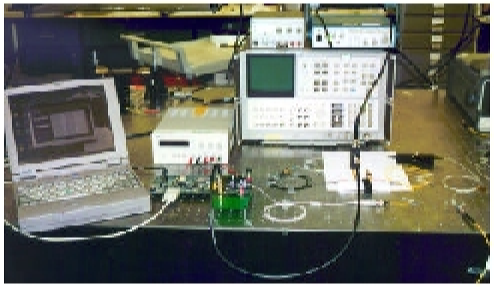
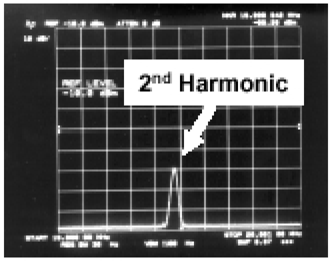
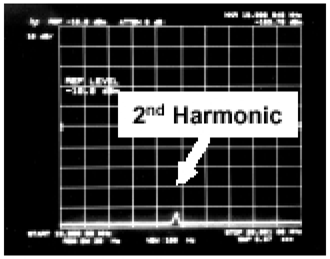
Measured Performance of Bias Control Loop





Loop Open



Loop Closed

Digital Feedback Loop achieves

20dB suppression of 2nd order distortion

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jalali@ucla.edu

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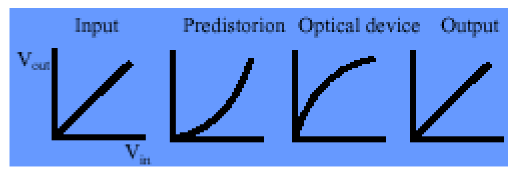
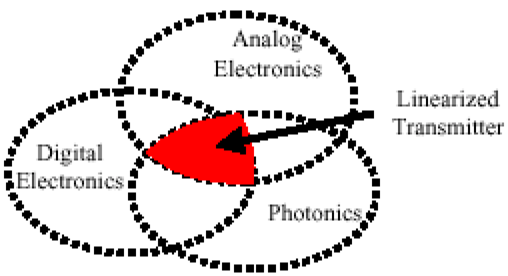
Electronic Linearization of Fiber Optic Links

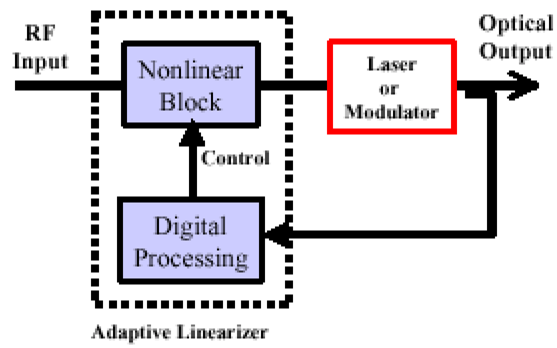
PI: Bahram Jalali - UCLA
Co-PI: Babak Daneshrad - UCLA

Objective:
Develop adaptive linearizer for linearization of direct and externally modulated optical transmitters.

Approach:
Nonlinear circuit pre-distorts the RF waveform to cancel nonlinearity of the optical transmitter. Digital feedback loop adapts the predistortion generator to the laser or modulator transfer function.







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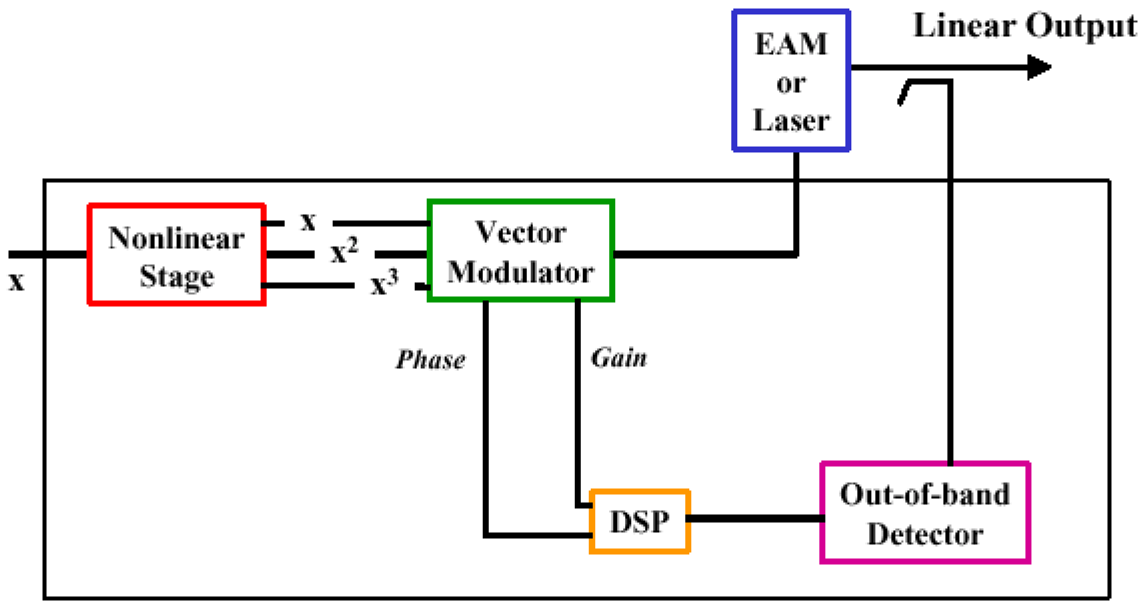
Adaptive Predistortion Linearizer



Closed-loop Adaptive Predistortion IC

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Tasks

SOW 4.1.1 System level design and simulation. Develop simulation environment for the linearized photonic link.

SOW 4.1.2 Input predistortion generator and output distortion detector design and IC fabrication.

SOW 4.1.3 ASIC DSP development and IC fabrication.

SOW 4.1.4 Link test and characterization.

SOW 4.1.5 PCB Packaging

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jalali@ucla.edu

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